The CRUSHED STONE JOURNAL

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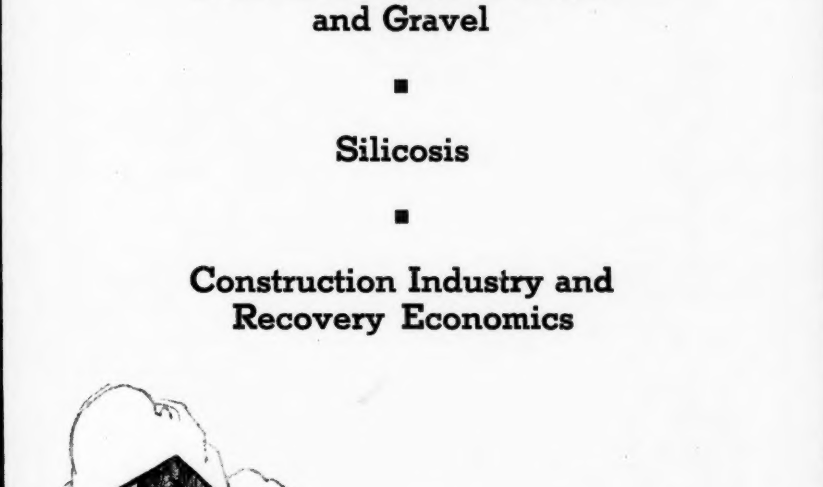

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J. R. BOYD, Editor

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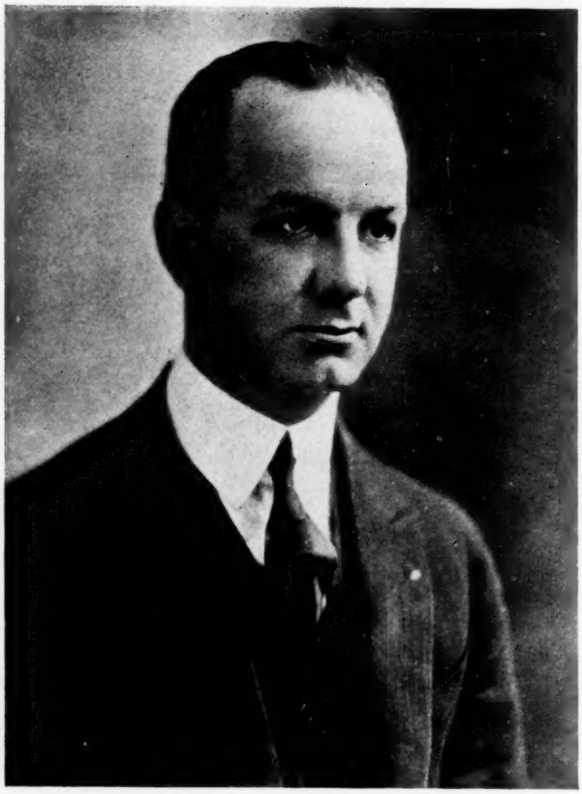

C. S. HUNTINGTON

Link-Belt Company, Chicago, Illinois

elected Chairman of the Manufacturers' Division of the National Crushed Stone Association, to fill the unexpired term of the late Gordon Buchanan

THE CRUSHED STONE JOURNAL

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The Significance of Accelerated Soundness Tests on Stone and Gravel

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Unsoundness in aggregates may contribute to the disintegration of concrete exposed to the weather, but there are a number of other potent contributing factors. Too frequently aggregates are adjudged unsound because they show a percentage of loss in an artificial, accelerated weathering test in excess of some arbitrarily chosen amount. In the present article evidence is presented showing that the sodium sulfate accelerated soundness test may not be entirely reliable and its indications should be regarded primarily as a danger signal which should be checked against service behavior.

ALL construction materials, when exposed to the elements, undergo change; this is a matter of common observation. Alteration in the original structure of the rock is brought about by physical or chemical effects or both. All of the well-known natural phenomena which are so effective in breaking down even the most durable of rocks as they occur in nature are equally effective in their action against these same rocks when they are used as structural materials.

Durability is a relative term. A comparatively non-durable material, considered from the standpoint of the geologist, may still be a useful and durable structural material for the particular kind of structure or the particular kind of exposure condition under consideration. Monumental structures are built with the hope they will last for centuries; office buildings with the practical certainty that obsolescence will govern their useful life; highways have an even shorter life, controlled to a varying degree by weathering effects and by the physical effects of traffic. The various structures in which stone and gravel are used are subjected to different degrees and kinds of exposure. Thus, an interior column may be continuously dry and not exposed to any great change in temperature. The footings of those same columns may have to combat the leaching action of continuous moisture. Outside exposure in a wet, cold climate will be far more severe than similar exposure in a dry, warm climate. Aggregates suitable for one condition may not be suitable for another.

In considering the materials for use in any structure, quite obviously the durability of those materials for the component parts of the structure with their different exposure conditions should be considered just as carefully as the stress-resisting properties of those materials. Sometimes mineral aggregates are used uncombined with cementing media, for illustration, as in sewage disposal trickling filters, but most commonly they are used in the form of concrete and when so used, it is pertinent to inquire regarding the exposure to which the concrete will be subjected, for the severity of the exposure condition influences the rapidity of disintegration.

Unsound aggregates have a different effect on the durability of concrete depending upon the kind of disintegration which takes place in the aggregate upon exposure to the weather and also upon the percentage of unsound aggregate present in the con-

crete. There are two general types of concrete failure due to unsound aggregates, namely, "pitting" and "spalling", but pitting of the concrete surface is much more common than spalling. Pitting is caused by the disintegration of weak, porous stone when subjected to the action of frost or water and such disintegration takes place with very little volume change of the aggregate. On the other hand, spalling of the concrete is produced when unsound aggregates of another class disintegrate under the action of freezing and thawing. Such aggregates are generally rather hard and strong initially, although they may be badly seamed. When they take up water and freeze, they expand with considerable force, thus producing either surface cracking in the concrete or ultimately they spall the concrete and form craters in the surface.

Typical of the first class of unsound aggregates are the argillaceous limestones and sandstones, shales, soft, friable, porous sandstone, etc. The failure of such aggregates is most likely to cause pits in the surface of the concrete which do not extend very deep and which lead to no particular harm. Naturally, if such fragments are present in high percentages, a general weakening of the concrete will occur, although there is evidence that coarse aggregates in concrete are protected to a considerable extent by their surrounding layer of mortar, assuming, of course, that the mortar is resistant to the weather.

Perhaps the principal offender in the second class of unsound materials which produces spalling of the concrete is chert, although all cherts do not behave in the same manner, for some of them are entirely sound. Certain laminated rocks may cause spalling when sound material is interlaid with unsound material. For illustration, limestone may be laminated with layers of shale which upon taking up moisture and freezing, may cause expansion of the concrete and spalling. If this type of unsound material is present in the concrete in a high percentage, something more than mere surface spalling will take place. The concrete may suffer complete disintegration, particularly if it is subjected to severe exposure conditions and if the mortar is not highly resistant. Such aggregate is dangerous and capable of causing a great deal of trouble.

Certain improperly made blast furnace slags containing partially burnt limestone, which in some way has gone through the blast furnace without complete combination with the silicious material in the iron ore have been a source of spalled concrete. Such material is hard to detect by any form of accelerated soundness test, largely because of the difficulty of obtaining a sample containing the dangerous material.

The so-called "chocolate-bars" of Iowa and Minnesota which occur in some of the gravels in those States are also sources of spalling in concrete. These are ferruginous secretions forming hard and firm fragments with a soft core which is said to be usually composed of clay. Chocolate-bars likewise have caused disruption of concrete. Certain isolated examples of unsound aggregates have been reported from time to time, one of them being composed of a feldspathic type of material which caused serious disintegration of the concrete.

Although unsound aggregates are known to be possible sources of trouble in concrete, it will be well to remember that the disintegration of concrete due to the presence of unsound aggregates is the exception rather than the rule. The durability of concrete, for the most part, is controlled by the durability of the mortar and, in general, most lack of durability can be traced to the presence of too much water in the concrete before it has hardened. This defect may be caused by either the use of too much mixing water or by so-called water-gain due to the heavier portions of the concrete displacing the excess water to the surface during the depositing operation.

Aggregates do at times cause trouble, however, and in recognition of this fact accelerated methods for detecting unsound aggregates have been devised. It is attempted by the use of accelerated tests to determine in a short time whether the aggregates will remain sound over a period of years. The tests most commonly employed are the Sodium Sulfate Soundness Test or the Magnesium Sulfate Test and in a number of laboratories freezing and thawing tests are also made. Experiments likewise have been conducted on the use of boiling and also with the use of an auto-clave in which the aggregates are steamed under pressure and that pressure is suddenly released.

The sodium sulfate soundness test or the Test for Soundness of Coarse Aggregate by the Use of Sodium Sulfate, C89-32T, is now a tentative standard of the American Society for Testing Materials and it would seem fitting to discuss this test for the purpose of pointing out its seeming weaknesses and its applicability in the detection of unsound aggregates.

Briefly, the method consists first in the preparation of a saturated solution of sodium sulfate. This is done by dissolving either anhydrous sodium sulfate, Na_2SO_4, or crystalline sodium sulfate, $Na_2SO_4.10H_2O$,

in water at a temperature of 24° to 27°C. (75° to 80°F.), additional salt being used as may be necessary to insure saturation. The solution is allowed to cool to a temperature of 21°±1°C. (70°±2°F.). Stated amounts of designated sizes of coarse aggregates comprise the sample which is immersed in the solution for a period of 18 hours during which time it is supposed to be kept at a temperature of 70°F.±2°F. After 18 hours of immersion, the sample is removed from the solution and is put in a drying oven, previously brought to a temperature of 105° to 110°C. (221° to 230°F.), where it is dried to constant weight. Then it is allowed to cool to within the range of temperature specified for the solution, that is, to within 68° to 70°F. when it is again immersed. Unless otherwise specified, five cycles of this treatment constitutes a test. Finally, after the last cycle when the sample has cooled, it is washed free of sodium sulfate; the sample is dried to constant weight and screened over the same sieve on which it was retained before the test. The material passing this screen is considered as lost because of unsoundness of the stone or gravel. Crystallization of the sodium sulfate within the rock is intended to simulate the disrupting action of the frost.

There are several weak points in the test which is now a tentative of the A. S. T. M. Solubility curves for sodium sulfate show that, at the temperature required by the test, the rate of solubility changes rapidly and if particular pains are not taken to see that the required range of temperature is not exceeded during the immersion of the specimen, crystallization of the salt may take place owing to a slight fall in temperature. It is highly important that the temperature be kept practically constant during the period of immersion. Another serious objection to the A. S. T. M. test is the manner of determining the percentage of loss of the individual fractions. It will be noted that the same sizes of sieves are used for determining the loss of each fraction as were employed in the preparation of that fraction of the sample. It may well happen that fragments which are just retained on that sieve in preparing the sample are slightly chipped as a result of the sodium sulfate test and in consequence thereof they pass through the sieve at the conclusion of the test and are thereby recorded as being unsound. Had these same fragments been just a little bit larger, they would have been retained on the sieve at the conclusion of the test and would, accordingly, be recorded as sound. It frequently happens that aggregates are so graded that one sample may have a high percentage of its fragments in a given fraction just above the minimum size sieve used in the preparation of that fraction. On the other hand, another sample may have the bulk of its fragments very much larger than the minimum size sieve used for preparing the fraction. The first sample would have a high percentage of loss and the second sample, a low percentage of loss even though both samples were composed of identical materials. It is obvious that this is a serious defect in the method of making the test and the remedy would be to designate a smaller sieve for determining the percentage of loss than was used in the preparation of the sample. It would seem that the sodium sulfate test is not sufficiently definite to lend itself to quantitative determination of loss in the above manner. It may well be that some of the fragments, although badly cracked and split due to the action of the test, still are retained on the sieve. They obviously are unsound, but are not so recorded.

Other methods of making the sodium sulfate test, notably that of the American Society of Civil Engineers Committee on Filtering Materials employs a somewhat less definite method for determining the percentage of loss in a quantitative way.

The essential features of the A. S. C. E. method are as follows: The sample is composed of 10 to 20 fragments of stone, of about the same size. The sodium sulfate solution is prepared by the use of anhydrous sodium sulfate dissolved in water heated to 85° to 90°F. to make a saturated solution which is cooled before using. The sample is soaked in the sodium sulfate solution for 19 hours and the pieces removed one by one and carefully examined for any signs of failure. Then the entire sample is placed in shallow pans in a previously heated oven and maintained at 100° to 105° C. for 4 hours. The sample is then removed from the oven and allowed to cool for 1 hour after which it is re-immersed. When applied to material for use in trickling filters the test consists of 20 cycles. The rating of the specimen is computed as follows:

a. Each of the fragments in the sample is allotted a percentage equal to the proportion it is of the total sample. For illustration, one piece would be 5 per cent of a 20-piece sample.

b. An individual specimen breaking into 3 or more pieces, or which is so cracked that such breaking is obvious, is considered to have failed, provided each portion is more than 10 per cent of the original weight of the piece.

c. The percentage by weight of chips, spalls and flakes from the remaining pieces passing the ½ inch No. 2 mesh sieve is used for determining the percentage of loss.

d. The rating of the sample is 100 minus the percentage of lost material, including the pieces which have completely failed.

This method is at least free of the objection cited against the A. S. T. M. method, namely, the use of the same size sieve for determining loss as was used in the preparation of the sample. It has a further point in its favor, namely, the material which is considered as being lost is more definitely the material which has failed, although there is still some doubt whether a fragment of stone which merely splits into 3 pieces should arbitrarily be designated as an unsound fragment of stone. Perhaps this would be so for sewage disposal work, but there is considerable doubt as to whether such a fragment would cause any trouble whatsoever in concrete.

The sodium sulfate accelerated soundness test is an artificial way of simulating the expansion force due to the formation of ice within the pores of the aggregates and the question naturally arises, why a direct freezing and thawing test will not more nearly simulate the freezing action which takes place when stone is exposed to the weather. A number of laboratories have experimented with freezing and thawing tests, but thus far no standard method has been devised. In brief, there are three general methods employed for conducting freezing tests and many variations of these are possible. Method 1. The sample of stone is water-soaked and is then subjected to freezing in a freezing room. The sample may be totally immersed in water, partially immersed, or placed in the air during freezing. Method 2. The sample is placed in a freezing cabinet, such as an ice cream cabinet, in a can which is immersed in alcohol contained in the compartment of the freezing cabinet. The purpose of the alcohol is to convey heat away from the specimens rapidly and thus produce rapid freezing. In this case the specimens may be totally immersed, partially immersed, or merely placed in the air after having been water soaked. Still a third method calls for the immersion of a saturated sample in the calcium chloride brine solution. This brings about extremely rapid freezing.

The severity of these three tests seems to depend upon the rate at which freezing takes place. Method No. 1 is least severe; method No. 2 of intermediate severity and Method No. 3 is extremely severe in its action. This was well demonstrated by a series of cooperative tests conducted several years ago between the (P. C. A.) Portland Cement Association, the University of Minnesota and the National Crushed Stone Association. Without going into the details of the test, it was noted that Method No. 1 seemed to be lacking in severity to such an extent that 500 cycles of freezing and thawing produced very little failure even on mortars containing shale as a fine aggregate. Method No. 3 produced practically complete disintegration with less than 1/10 the number of cycles, whereas Method No. 2, while not as rapid as Method No. 3, still, gave results in a reasonably short period of time which would place the test in the class of accelerated methods. Method No. 2 is the method now used in the laboratory of the National Crushed Stone Association and except for the fact that we now use complete immersion, the method described in the July, 1929, *Crushed Stone Journal* is an accurate description.

Other methods of freezing and thawing have been used and dry ice lends itself to the performance of this type of test.

Thus far, the discussion on the two main accelerated soundness tests would seem to lead to conclusions as follows:

1. That the results obtained in the sodium sulfate soundness test may vary:

a. Because of the use of the same sieve for preparing the sample as for measuring the percentage of loss.

b. Due to slight variations in temperature of the solution or to other unexplained variations in the method.

2. The freezing and thawing accelerated soundness tests will give different percentages of loss for a given number of cycles, depending evidently upon the rate at which freezing takes place. It thus is insufficient to know that a sample has withstood a given number of cycles of freezing and thawing unless the exact procedure for making the test is known also.

An accelerated soundness test does not with certainty determine the soundness of an aggregate unless it is known that the results of that test agree with service behavior. The results obtained with the sodium sulfate test and the freezing and thawing test are only in fair agreement with one another, and there have been some notable examples of lack of agreement.

In the following table is shown the relation of freezing and thawing tests and sodium sulfate tests made on samples of stone, gravel and Portland cement mortar. It will be noted that in nine cases, freezing and thawing caused more disintegration than sodium sulfate and there are four cases in which the sodium sulfate test caused more loss than freezing and thawing.

RELATION OF FREEZING AND THAWING TEST AND SODIUM SULFATE TEST

Sample No.	Per Cent Loss: Freezing 50 cycles	Per Cent Loss: Sodium Sulfate 20 cycles
2	6	38
5	0	0
7	30	25
9	0	85
13	7	18
23	0	0
27	0	0
32	0	0
35	31	5
17	0	0
24	13	4
31	0	0
I	0	0
II	34	0
III	100	44
IV	71	40
V	6	0
VI	100	19
VII	27	2
51	0	2

Note: Samples I to VII are Portland cement mortars and the remaining samples are stone and gravel.

The question may properly be asked, Does it necessarily follow that if a specimen fails in an accelerated soundness test, that the concrete will also fail when subjected to the weather?

The answer to this question cannot be given with certainty. In the first place, the severity of exposure has much to do with the possible failure of the concrete. If the concrete remains dry and the temperature is above freezing, there seems little likelihood of failure even though the aggregate used is unsound as shown by accelerated soundness tests. On the other hand, it may well be that serious failure of the concrete will take place, even though sound aggregates are used as revealed, not only by accelerated tests, but by the behavior of the material in the ledge. As has been previously pointed out, failure of the aggregate is not the only kind of failure which takes place in concrete and failure of the mortar, due to excess mixing water, is a much more prolific source of failure than that due to the aggregate.

The above table which is discussed more fully in the July, 1929, issue of the *Crushed Stone Journal,* is rather enlightening in showing the effect of excess moisture, particularly when viewed in the light of the information given in the table which follows:

QUANTITIES OF MATERIALS USED IN MORTAR TESTS

No.	Mix by Wt.	Cement lbs.	Sand lbs.	Water lbs.	Flow (½″ drop)	Water-Cement Ratio	Combined Water lbs. (estimated)	Free Water lbs. (estimated)
I	1:1	55.0	55.0	19.4	163	0.53	6.9	12.5
II	1:2	36.6	73.2	21.6	165	0.89	5.1	16.5
III	1:3	27.5	82.5	22.2	176	1.22	4.8	17.4
IV	1:4	22.0	88.0	22.9	164	1.57	4.2	17.7
V	1:2	36.6	73.2	19.2	169	0.79	5.1	14.1
VI	1:2	36.6	73.2	29.0	300+	1.19	5.1	23.9
VII	1:2	36.6	73.2	23.3	205	0.96	5.1	17.2

It will be noted in the above tables that the extent of failure of the different mortar specimens goes more or less hand in hand with the amount of free water present in the respective mixtures. The free or uncombined water, upon evaporation, leaves pore spaces which give access to the infiltration of water which may subsequently freeze and start disrupting action. It is interesting to note that the resistance to freezing and thawing of the mortar seems to bear more definite relation to the free water than to the water-cement ratio.

Tests show that sometimes stone which will fail in an accelerated soundness test will not fail when used in concrete, even after it has been exposed due to the failure of the mortar. A case in point might be of interest. Five different limestones were subjected to ten cycles of freezing and thawing in accordance with the National Crushed Stone Association methods. These various stones showed failure, varying from approximately 30 to 50 per cent of the respective weights of the original samples. They were used in concrete of 1:2:3½ proportions and when the concrete specimens were subjected to 85 cycles of freezing and thawing the only effect was on the mortar which seemed to be softened and so disintegrated as to expose the coarse aggregate. This is a rather clear indication that it does not necessarily follow, because a coarse aggregate, when subjected to a freezing and thawing test, shows rather bad failure, that the concrete from which it is made will also show failure. A similar freezing test was made on four samples of concrete, three of them containing coarse aggregate which was open to some question when judged by the sodium sulfate test alone. The fourth sample of aggregate would be considered

sound when judged by this test; yet these four samples of concrete when exposed to 75 alternations of the freezing and thawing test showed an external appearance about alike in all cases. In all of these samples the mortar had disappeared from the surface and had exposed the coarse aggregate. One of these aggregate was from Illinois and this particular sample gave rather poor results in the sodium sulfate test. The concrete was of 1:2:3½ proportions by loose volume, with water-cement ratios varying from 0.80 to 0.88.

At the Eleventh Annual Meeting of the Highway Research Board of the National Research Council held in Washington in December, 1931, a report was submitted by Mr. Verne McCown for the Mineral Aggregates Committee in which were summarized reports from various institutions bearing on the subject, "The Significance of the Sodium Sulfate and Freezing and Thawing Tests on Mineral Aggregates." It will be impossible in the present report to summarize the various conclusions drawn by the authorities quoted, but the following statements excerpted from the above report bear particularly on the significance of accelerated soundness tests as applied to aggregate.

In Illinois the samples which have given the most trouble are of argillaceous limestone or of chert. Apparently, certain of the argillaceous limestones which fail badly in both the sodium sulfate test and the freezing and thawing test, have given poor results in service. On the other hand, another sample of argillaceous limestone showing failure to sodium sulfate tests to not so marked an extent as the other samples does not give poor results in service. A sample of chert which is not much affected by the sodium sulfate test, but breaks down in a few cycles of the freezing and thawing test, has shown bad results in service.

The Iowa tests cite a sample of cherty limestone, not much affected by the sodium sulfate test, but showing extensive subdivision under the freezing and thawing test. This material contains from 0.5 to 10 per cent of chert and when used in pavement construction produces some surface spalling but no further disintegration. Apparently, in the Iowa laboratory, 16 cycles of freezing and thawing are considered equal to 5 cycles of the sodium sulfate test.

In the Tennessee report, it is stated that the presence of shale in coarse aggregate did not materially influence the transverse strength of concrete beams in amounts up to ten per cent of shale. There was some reduction, however, in compressive strength. Greater variation in strengths occurs among specimens of the same series caused by different methods of curing than was apparently due to the different percentages of shale used.

In Pennsylvania, 5 cycles of the sodium sulfate test are considered adequate for determining the soundness of coarse aggregate using the American Association of State Highway Officials method. One case is cited of a bad concrete failure but in this case the aggregate would have failed within a few cycles of the sodium sulfate test.

In New York it is specified that in the sodium sulfate test, using 5 cycles, the stone shall lose not more than 15 per cent by weight.

One of the important conclusions from the National Crushed Stone Association tests is that coarse aggregate, even though in some cases unsound, does not necessarily make for unsoundness in concrete. The unsound stone tested did not crack the concrete, nor did the stone leave the concrete or cause pitting. Only after the mortar had failed did the stone fail by continuous chipping.

The conclusions drawn from the Wisconsin tests are based on a sample from each of 21 quarries representing four types of Wisconsin limestones. Weathering tests consisting of 80 or more reversals of freezing and thawing of continuously immersed samples occasioned relative disintegration comparable with that which might have been expected from field inspection.

A part of the Minnesota conclusions reads, "A relationship exists between the durability of coarse aggregate and the durability of concrete made therefrom. A cement paste of concrete specimens used in freezing and thawing tests intended to reveal the durability of the aggregate should be of such quality at time of test that disintegration will depend more on aggregate quality than paste quality."

Kansas suggests that tests of aggregates should include tests in concrete before any source is condemned. Alternate freezing and thawing is a valuable method of studying the durability of concrete and concrete aggregates. The durability of concrete is greatly affected by the quality of the cement paste. A water-cement ratio of 0.8 or more is not likely to give concrete of adequate durability under severe exposure conditions. The use of unsound aggregate produces unsound concrete, the resistance of the mortar being only slightly effective in protecting the aggregate. Any aggregate containing absorptive chert should not be used until after careful investigation. The character of failure of aggregate is fully

as important as the extent of the failure,—material which breaks into a few pieces with disruptive force, as chert, being much more detrimental than material which completely disintegrates, but not with such expansive force.

The Committee on Mineral Aggregates in commenting on the material from the various authorities quoted, points out the following indications:

1. Certain argillaceous rocks and non-durable materials and some cherts cause failure of concrete in which they are used when exposed to freezing and thawing in the presence of moisture.

2. The extent and rate of failure probably depend upon the amount of the unsound material in the concrete. This amount is still open to question.

3. Failures of concrete when due to coarse aggregate, seem to be of two general types,—one where the aggregate disintegrates without much volume change and, the other, where the aggregate undergoes sufficient volume change to disrupt the concrete.

4. Data on failure of concrete caused by unsound fine aggregates are somewhat conflicting and inconclusive.

5. Extensive investigations indicate that an accelerated freezing and thawing test is valuable for the study of durability of concrete and aggregates.

6. There is a conflict of opinion as to the value of the sodium sulfate soundness test.

7. The use of present day soundness tests of aggregates as acceptance tests is questionable owing to lack of correlation with service conditions.

8. All investigators agree, assuming the freezing and thawing test is a measure of durability, that the quality of the mortar or cement paste is probably the most important influence on the durability. High quality of mortar with low water-content makes concrete very resistant to freezing and thawing, even when aggregates considered unsound are used.

9. Further investigations of soundness and durability are needed, both in the laboratory and in the field.

Certain well-known national specifications recognize the uncertainty of accelerated soundness tests and the greater certainty of service behavior as a criterion of soundness. For illustration, the Federal Specifications Board specification which governs purchases by the Federal government reads as follows:

"E-2c. Soundness and resistance to abrasion.

"E-2c (1). Grade A crushed stone and gravel shall be considered to have met the requirements for soundness and resistance to abrasion provided evidence satisfactory to the Government can be furnished showing that the material has proved satisfactory as coarse aggregate in concrete which has been subjected for a period of at least 5 years to essentially the same conditions of service and exposure as the structure in which the material is to be used.

"E-2c (2). Grade A crushed stone failing to meet the requirement given in section E-2c (1) shall be subjected to the standard Deval abrasion test for stone and to the accelerated sodium sulphate soundness test and shall meet the following requirements:

	Per cent
Percentage of wear, not more than............	7
Loss in sodium sulphate test, not more than....	15

"E-2c (3). Grade A gravel failing to meet the requirement given in section E-2c (1) shall be subjected to the modified Deval abrasion test for gravel and to the accelerated sodium sulphate soundness test and shall meet the following requirements

	Per cent
Percentage of wear, not more than............	15
Loss in sodium sulphate test, not more than....	15 "

In conclusion, I shall not attempt to improve on the comments made by the Mineral Aggregates Committee of the Highway Research Board. I think the question of the significance of accelerated soundness tests on aggregates can best be summed up by saying that when an aggregate fails in accelerated soundness tests, it should be looked upon with suspicion, but that before it is condemned the service record of that aggregate should be thoroughly investigated. Accelerated tests are not infallible and their relation to service behavior is not definitely established.

Silicosis[1]

An Interpretive Review of Accumulated Experience

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◆ In view of the present widespread interest in the problem of silicosis, apparently accompanied by a surprising amount of misinformation, the following review by Dr. Sappington should prove of especial interest and value.

THE recent and widespread interest manifested in silicosis, together with the economic considerations involved, is without precedent in the history of occupational disease in American industry.

Because there has been a definite lack of appreciation on the part of industrial managers concerning the importance of industrial health work, and also because it has been extremely difficult to convince them that this type of work is a valuable investment, numerous organizations are finding themselves in legal difficulties; some of these claims are unjust, but many could have been avoided by the proper type of health protection.

Silicosis is not a new disease, it having been first demonstrated by an Italian named Ramazzini, as early as the year 1700. Various experiences have furnished us with a great deal of scientific data, particularly the British experience in South Africa, the Australian experience, and more recently the Canadian experience.

In spite of all this background, there seems to be a general lack of definite information both on the part of industrial physicians and industrial laymen. It is because of all of the above reasons that this material—believed to be a brief but comprehensive discussion of the important points—is written especially for the use of persons interested in the protection of industry and its employees.

What Silicosis Is

Silicosis is a disease of the lungs in which there is a general replacement of the normal elastic tissue by unyielding, inelastic fibrous tissue; it is caused by the continuous breathing of microscopic particles of free silica dust over varying intervals of time. This fibrous tissue replacement causes shortness of breath, decrease in lung expansion, and an increased susceptibility to tuberculosis.

It is important that a brief discussion of the descriptive terms now be given. *Pneumoconiosis* is a general scientific term applied to all types of dusted lungs, the literal meaning of the word being a "dusted" lung. *Silicosis* is probably the most important specific form of pneumoconiosis. Next in importance is *asbestosis,* caused, as the name implies, by the breathing of microscopic particles of asbestos dust; this form of pneumoconiosis also produces a definite and general fibrosis of the lungs, as serious or disabling, in so far as our present clinical experience goes, as silicosis, but not nearly as frequent in occurrence. There are other inconsequential and minor forms of pneumoconiosis such as *anthracosis* (caused by breathing coal or carbon particles); *siderosis* (caused by breathing particles of iron); and *chalcosis* (caused by the breathing of fine particles of copper). This should not be confused with the term *"chalicosis"* which is a general term similar to pneumoconiosis and means a pneumoconiosis caused by the inhalation of dust incident to the occupation of stone-cutting. Pneumoconiosis, however, is the preferable general term.

It should be repeated, for the sake of clearness, that silicosis cannot be contracted in any other way than by the breathing of microscopic particles of free silica dust. Clinically and mediocolegally, silicosis has no distinct cause or effect relationships to the other forms of pneumoconiosis, although dangerous amounts of free silica may be found in nature, along with other minerals and metals.

It would be useful to have a brief description of what happens when dangerous amounts of free silica dust are breathed in by exposed workers.

In the first place, we are concerned only with dust particles measuring under 10 micromillimeters in diameter, because it is only particles of such microscopic size that can get into the lung tissue proper. Since a micromillimeter is equivalent to one twenty-five-thousandths of an inch, it will be seen that dust particles which can cause trouble are microscopic in size and cannot be observed or counted except by microscopic methods.

The air sacs of the lungs, the smallest structure in the lungs, are also of microscopic size. In a mi-

croscopic cross-section of an air sac the air space will be seen in the middle, around which are very thin microscopic walls, in which are the blood and lymph vessels. When particles of dust come into the air space in the middle of the air sac (as shown in cross-section view under a microscope) the so-called devouring cells, which are the phagocytes or white cells of the blood, are attracted and migrate through the walls of the vessels into the air space. These devouring cells then actually surround foreign material or dust particles and again migrate through the wall of the air sac, through the walls of the blood and lymph vessels and are carried by the blood and lymph streams to various portions of the body.

When the number of dust particles becomes considerable, the number of devouring cells not only blocks the lymph glands which are encountered in the course of lymph vessels, but also in many instances these cells disintegrate, leaving free silica in the glands, which then undergo fibrosis. This is what makes them visible in X-ray pictures, because of the increased density resulting from the formation of fibrous tissue.

Following this, there is a backing-up of the devouring cells and their enclosed dust particles into the lungs proper, and here a fibrous tissue replacement also takes place.

The nature of free silica particles is such that they produce an irritation of the connective tissue elements of the lungs resulting in the formation of fibrous tissue. This effect follows because of the irritant properties of free silica particles and is accomplished through both physical and chemical changes before and during the production of fibrous tissue.

Eventually fibrous tissue develops in small, well-defined and limited nodules, as they are called, throughout the entire lung tissue. Since these nodules are more dense than the lung tissue itself, they show in the X-ray picture, giving an appearance which is called "nodulation."

It must be remarked that not all persons are alike in the rapidity with which they develop silicosis under similar conditions of exposure.

However, there is no immunity, natural or acquired, by which any individual may feel that he is entirely safe from the contracting of silicosis, if exposed to conditions which ordinarily produce this disease.

Neither is there any known way by which a person may be free of silicosis after he has developed it. One of the important points about silicosis is its progressiveness; after a victim has reached the third stage, and, in some instances, the second stage, the disease goes on to a fatal termination, even if the employee has been removed from further exposure. This is what is called a "progressive" type of lung pathology.

How Silicosis Is Contracted

It is well to repeat here that silicosis is caused by the breathing of harmful amounts of free silica, which eventually produce a fibrous change in the lungs, replacing the normal lung structures.

These are four important points in the production of silicosis:

1. Number of particles per cubic foot of air.
2. Particle size of dust.
3. Mineral composition of the dust.
4. Length of exposure.

Previous comment has been made on particle size, stating that it is only particles of less than ten micromillimeters in diameter that can cause trouble, because only these can get into the lungs.

The number of particles of dust per cubic foot of air (sometimes called the concentration of the dust) and the mineralogical composition of inhaled dust should be considered together in rating a possible hazard due to the production of dust in various industrial processes. It has been found, for instance, that where concentration of the dust is greater than twenty million particles per cubic foot of air and the mineralogical composition shows a quartz content of 35 per cent or over, silicosis may be contracted. It is obvious that there will be many situations in industry where the concentrations will be quite variable and also where the quartz content will be different; in such instances, it is only through a great deal of judgment and experience that one can assign a health hazard rating to the specific conditions as found.

Our ideas concerning the length of exposure in the development of silicosis have undergone a change within recent years. It was formerly thought that ten years was about the average exposure in cases of silicosis which had developed. It is now known that a number of cases of silicosis have developed in much less than 10 years' time. For instance, in some of the Canadian silicosis laws, before a man can get compensation, it is required that he show a minimum of three years' exposure in stone-cutting occupations and a minimum of five

years' exposure in other occupations. From these regulations, it would seem that the average time necessary for the development of cases of silicosis is less than ten years. There are unusual instances on record where employees have developed silicosis within varying periods of two to three years, but these occurred under certain unusual conditions, where the nature of the material handled was of such a concentration, fineness of particle size, and quartz content as to be different from the usual dust conditions encountered in industrial processes.

Among the dusts which contain harmful silica, capable of producing silicosis, the most common sources are silicon dioxide or sand, granite, quartz, and the various kinds of sandstone. These substances contain free silica in various amounts.

On the other hand, the so-called combined silicates such as clay, talc, and feldspar have so far not been proved capable of causing fibrosis in the lungs. One combined silicate, namely, asbestos, was previously mentioned as causing fibrosis, as serious and extensive, but not as frequent however, as free silica.

Ordinarily, coal and lime dusts are classified as non-silica-containing dusts. In certain veins, however, anthracite coal contains an appreciable amount of free silica which may produce fibrosis; bituminous or soft coal contains only a very small amount of free silica, generally considered to be non-injurious.

It is likewise important that some statement be made concerning the relative danger of various industrial processes and occupations. Without going into detail on this subject, it is important to keep in mind that in any occupation or process where fine particles of dust are produced when using sand, granite, quartz, and different varieties of sandstone, a potential silicosis hazard exists. The point to be stressed is that these dust particles must be fine enough to get into the lungs; therefore, in occupations and processes involving the impingement of sand against hard surfaces or the pulverization of the materials mentioned above, it is reasonable to believe that a definite silicosis hazard may be present.

How Silicosis Is Detected

The British, South African, Australian, Canadian, and more recently the American experiences have all yielded scientific information relative to the diagnosis of silicosis. Diagnostic standards are now available and agreed to by the different authorities in this country.

In the diagnosis of silicosis, it is an obvious point that the occupational history must show exposure to the inhalation of free silica dust of sufficient concentration and for a sufficient period of time to be considered the reasonable cause of clinical findings. Both previous and immediate occupational histories should be included in the review.

Three stages of silicosis are recognized. The symptoms of early silicosis are few and they are often indefinite. There may be no other symptoms than those of a common cold. The most usual symptoms are slight shortness of breath on exertion, unproductive cough, and recurrent colds. There may be less ability to expand the chest than usual and the elasticity of the chest may be slightly impaired. The usual and normal breath sounds may be somewhat harsh, roughened and shortened.

The second stage is usually manifested by a definite shortness of breath on exertion and frequently there are pains in the chest. Dry morning cough, sometimes with vomiting, and more frequent recurrence of colds may be noted. The patient may not lose flesh and may appear robust, but the shortness of breath may interfere with his working efficiency. The chest expansion is noticeably decreased, and chest movements apparently are smaller. The breath sounds are similar to those in the first stage, but the change is more definite.

In the advanced or third stage, the symptoms are still more severe with a marked shortness of breath which may be distressing; there is more coughing and some expectoration. The patient is unable to work, loses flesh, the chest expansion is greatly decreased, sometimes with forced inspiration and the pulse rate is frequently increased. Pain in the chest is more frequent, usually dull, but may be severe. Unless accompanied by infection of lung tissue, the patient usually is erect and well-nourished. Expansion is more limited than in the other stages. There are local areas of dullness, evident on chest examination, and the inspiratory breath sounds are shortened, roughened, or more harsh.

In general, the symptoms increase in severity as the disease progresses, but there is no sharp dividing line between any of the stages. Furthermore, the symptoms and physical findings cannot be construed as being diagnostic of silicosis, to the exclusion of other respiratory affections. The capacity for work decreases definitely at each stage, in direct proportion to the increase of severity of the symptoms.

The X-ray findings are very important, since it has been agreed by the majority of authorities that with-

out X-ray findings a positive diagnosis of early silicosis is quite difficult, if not impossible.

According to the South African experience, the only X-ray findings which are considered to be characteristic of the presence of silicosis are known as "nodulation" of the lung fields, produced by the well-defined rounded shadows which are cast by individual nodules, previously described.

It is believed that the earliest characteristic radiographic changes can be said to be a generalized linear fibrosis throughout both lungs fields with a partial but definite and small characteristic nodulation. This is true in cases of so-called "uncomplicated" silicosis in which no infection is present.

In the second and third stages there is a greater increase in the size of the mottling and a more extensive distribution, the expression "medium nodulation" being used to describe the characteristic appearance of the second stage and the "coarse nodulation" denoting the third stage.

Compensation Experience and Laws

The British with their experience in South Africa, Australia, and Canada have accumulated a large amount of valuable data in regard to compensation laws, and the cost of preventing silicosis and pensioning men who have contracted the disease. Millions of pounds have been spent each year. However, for the purpose of brevity, only the Canadian laws and experience will be considered here, for they are the most recent and the most likely to be of help to organizations in this country.

Three provinces of Canada, namely, Ontario, Saskatchewan and Quebec, have passed silicosis laws which provide for the protection of workmen in industries where hazards commonly exist.

The Ontario law may be taken as an example. To carry out the various procedures necessary, a silicosis commission composed of three expert physicians has been appointed; it is the duty of this commission to make employment examinations on all persons entering industries where there is a silicosis hazard, to make periodic examinations on all persons so employed, and to rate persons who have contracted silicosis.

The Ontario law provides that there must be a minimum of three to five years' exposure, three years in the stone-cutting trades, and five years in other industries, before a claim can be established leading to compensation.

The following provisions are made for the various stages of silicosis: in the first stage, showing the earliest detectable physical signs of silicosis which have been or are present, a lump sum of $500.00 is awarded, whether or not the capacity for work is or has been impaired; in the second stage, where physical signs are more constant and radiographic changes are also more characteristic, there is ordinarily some impairment which is usually not serious and permanent—for this stage a lump sum of $1,000.00 is awarded; in the third or final stage of silicosis, where the findings are rarely questionable, the impairment is considered serious and permanent and the employee is awarded two-thirds of his wages for the rest of his life.

It is obvious that when such definite provisions are made, settlements may be accomplished with less difficulty and on a more equitable basis.

In the United States, two types of compensation laws for occupational diseases exist in the various states: (1) complete coverage which includes compensation for all occupational diseases proved as such—these states are California, Connecticut, Massachusetts, North Dakota, Wisconsin, District of Columbia, and also Hawaii; (2) states in which there is specific coverage for occupational diseases as mentioned in the laws—so far as we know there are no states in the United States which mention silicosis specifically in the occupational disease list, which is to be found in the various state codes where specific mention is made. The majority of states, therefore, have made no provision for the coverage of silicosis.

In cases of third stage silicosis, and probably in some cases in the second stage, the claimant's position is this: in these well-established cases, which have been definitely proved to exist, we are not dealing with a permanent partial disability nor a temporary total disability, but we have for our consideration a permanent and total disability. The reason for this is that silicosis in the third stage and also in certain cases in the second stage, when once definitely established, continues to a fatal termination, even if the workman is removed from further exposure. The situation is also more exacting because there are no known means of successfully treating silicosis and curing it. Among medical men, silicosis is known as a "progressive" type of lung disease. There is some evidence, however, in the Canadian experience and compensation laws, that first stage silicosis and possibly some cases in the second stage may achieve normal expectancy of life

if removed from further exposure. Each case, however, must be decided upon its own merits with reference to this point. It should be emphasized and repeated that every claim rests solely on the proof that the man has or does not have silicosis.

From the manufacturers' point of view, the best possible thing that can happen to him is to be in a state where there is compensation for silicosis and to provide adequate manufacturing equipment and protective equipment for his employees; experience has proved that where this is done, the manufacturer pays less and in some cases very little for cases of silicosis. The next best thing that can happen to a manufacturer is to be in a state where compensation is provided for silicosis, although he has not been in a position, or thinks he has not been in a position, to provide proper manufacturing equipment and proper protective equipment for his employees—for should they develop silicosis, he at least has a fee schedule to conform to and the decision depends upon a special commission. The worst possible thing that can happen to the industrial defendant is to be in a state where there is no compensation provided for silicosis and also not to provide adequate manufacturing equipment and proper protective equipment for his employees, the reasons for this being obvious.

How Industry Can Protect Itself and Its Employees

There are four general ways in which industry can protect itself and its employees against the hazards of silicosis before the new employee has been exposed. These procedures are as follows:

1. (a) *A careful occupational history,* in which definite detailed data are obtained regarding previous occupations, length of exposure to silicosis hazards, and especially whether the new employee is an experienced sandblaster or following some other occupation in which there has been known silicosis hazard.

   (b) *A careful physical examination,* in which is emphasized the possibility of finding evidence of previous exposure to free silica.

   (c) *A competent X-ray examination of the chest.* This includes a chest film, together with a reading of the X-ray findings.

   (d) *A dust study of plant conditions,* including a hygienic survey of the physical layout of the plant, an occupational analysis of employees, and data concerning the concentration, particle size, mineralogical content, and exposure of employees in terms of years.

By these procedures, sufficient information should be obtained so that the employer is reasonably sure that the new workman comes to him without having been previously exposed to enough free silica to have caused the beginning of silicotic processes in his lungs; he is also assured that the working environment of the employee is of such a nature that it is reasonably safe from a dust hazard.

It must be obvious that when an employee has had from three to five years' exposure to a definite silicosis hazard he is an occupational risk, regardless of the physical or X-ray findings, and for his own protection he should follow another occupation; that when the physical findings and the X-ray interpretation are positive, indicating the presence of silicosis, a similar occupational risk is encountered, regardless of the occupational history, which may have been difficult to obtain, or to which evasive answers might have been given; that where both the occupational history and the physical findings are somewhat obscure and indefinite, it may be possible to reach a definite decision by means of X-ray evidence alone. Most authorities are now agreed that the diagnosis of early silicosis is extremely difficult without X-ray evidence, and many times impossible without such evidence.

The diagnosis of silicosis is now on a very good scientific basis, standards having been agreed upon by several different groups. These standards are based mainly on the experience of the British in South Africa, Australia, and Canada.

2. *Protection of exposed employees.* This procedure can be accomplished by the purchasing of up-to-date manufacturing equipment, used in sandblasting or other processes, and also by the provision of personal respiratory protection for each individual employee exposed to silicosis hazards. It is acknowledged that both of these types of apparatus can now be purchased in the market and that they will accomplish the desired result of protecting the worker. It is fruitless to provide the proper type of manufacturing equipment and an adequate type of protective equipment if the previous procedures regarding occupational history, employment physical examination and X-ray evidence have not also been previously carried out; for employees may get through who have previously had damaging

occupational exposure or those actually having silicosis may be employed.

3. *Periodic examinations.* This includes a careful physical examination, looking especially for symptoms and signs of silicosis, and should be accompanied by a chest X-ray. Some companies having definite silicosis hazards are carrying out these procedures every six months, some every three months, while in others where the hazard is not so well defined, the interval is one year. Again it must be obvious that it will be time and money wasted to give these periodic examinations unless the procedures in paragraph 1, which include the pre-employment examination, occupational history and chest X-ray, have been properly carried out at the time of employment.

4. *Initial and periodic dust studies.* As previously described, dust studies are useful not only as a protective measure, but also can be used periodically for purposes of diagnosis or checking up plant conditions. Such studies should always be made whenever processes are changed or whenever the physical layout of the plant goes through any type of revision. It will be obvious that the use of dust surveys can be applied for methods of diagnosis and prevention.

If all of these procedures are properly carried through, in the light of our present knowledge, industry should not have any serious difficulty with future cases of silicosis.

Diagnostic data are now available for the industrial physician who would prepare himself properly, and there are enough men in the country considered as authorities, so that the proper kind of advice can be obtained.

There are two other important points which will be of definite aid to industrialists in protecting themselves and their employees. These are the proper maintenance of manufacturing and protective equipment and the education of the worker, giving him information as to the dangerous type of work he is performing and securing his cooperation in protective procedures.

The maintenance of equipment can best be accomplished by the inspection of it at periodic intervals by persons who are particularly delegated with this responsibility. In a number of experiences this has been successfully carried out through the cooperation and recommendations of safety equipment manufacturers, who are usually glad to render any assistance they can in the proper maintenance of protective devices.

It is obvious that unless industry has the cooperation of the worker in the proper maintenance of equipment and in the understanding of the hazards involved in his work no real progress can be made in avoiding silicosis. Management should, therefore, take the workmen into its confidence, dispensing simple but scientifically-grounded information relating to the involved hazards. It should also be a part of the plant health supervision program to provide the necessary machinery of supervision to the end that these measures are properly and continuously carried through.

Essentials for the Preparation of Defense of Claims

Here the situation is a bit different, because claims have been filed charging that the employee or employees have developed silicosis while working for the defendant. However, similar procedures are used here, as in protection, especially the diagnostic procedures. The following points are important:

1. Proof of adequate exposure.
2. Previous and immediate occupational history.
3. Physical and X-ray findings.
4. Review, analysis, and coordination of the findings and opinions of specialists.

Proof of exposure is very important, for there are different kinds of dusts which are not capable of producing silicosis. (It should be repeated that silicosis is a specific type of pneumoconiosis which is contracted only by breathing very small particles of free silica in certain concentrations, over a sufficient period of time to cause characteristic changes in the lungs.) Neither are all dusty occupations and processes capable of producing silicosis. The important thing to keep in mind is that the most dangerous processes are those involving the impingement of sand, granite, quartz, or the various types of sandstone against a hard surface, producing very small and microscopic particles of free silica which are capable of being breathed into the lungs. Likewise any process involving the pulverization of these silica-containing substances is also a dangerous hazard. It is important to know, therefore, the kind of material used (especially the amount of free silica contained in it), the process and occupation, the

length of exposure, and, if it can be obtained, the average size of the particles and the number of them per cubic foot of air breathed by the exposed workman.

Of particular importance to the employer in protecting himself against claims is a detailed occupational history of previous occupations before being employed by the company against which the claim is being made. There are a number of instances on record where workers have developed definite silicosis from ten to fifteen years after exposure, although the average runs from three to ten years. Although as previously mentioned, exceptional cases have been shown to have developed in less than three years, particularly in very fine pulverizing work, this situation is unusual and rare and occurs only under exceptional conditions of exposure.

Of importance also are the physical examination and X-ray examination findings. The settlement of whether a man has silicosis or does not have it certainly is based more on the physical and X-ray findings than on any other point. If any given workman does not have silicosis, there is no just claim. If the physical and X-ray findings show that he has silicosis, he obviously has a claim against the company, and the company must prepare its defense. Therefore, in the defense of claims, the first and most important procedure is to establish whether or not the claimant has or has not silicosis. Both physical examination and X-ray findings should be done upon the claimant subsequent to the filing of the claim, if possible. The examination findings and the X-ray findings should then be reviewed separately by men who are capable of giving scientific judgment. If these judgments agree in the case of the physical findings and the X-ray findings, there would appear to be definite evidence submitted one way or the other; if they do not agree, another review should be made to find out why there is no agreement.

Another important procedure in the establishing of responsibility for silicosis cases is the use of a scientifically conducted dust survey by which it is possible to determine the nature of the dust exposure; because all types and quantities of dust do not produce silicosis, great care should be exercised in the acquisition of definite knowledge concerning the exposure, before responsibility is placed.

Finally, the last essential in the preparation of the defense of claims is the selection of a medical referee of established reputation and an impartial viewpoint, who will review, analyze, and coordinate the findings and opinions of specialists whose previous opinions and judgments have been obtained; this referee should also act in the capacity of adviser in each case, working directly with the attorneys and claims agents who are representing the company defendant. The referee should not only know industrial conditions, which will or will not produce the disease, the medical aspects of silicosis itself, but also be conversant with the laws, and the general silicosis situation over the country as a whole.

Conclusions

A brief discussion has been given covering information on what silicosis is; how it is contracted; how it is detected; compensation experiences and laws; how industry can protect itself and its employees from future cases of silicosis; and an outline for the preparation of the defense of claims.

It is not claimed that this brief statement is exhaustive or comprehensive enough to cover all cases or all series of cases of silicosis. References to literature and other details may be secured on request.

C. S. Huntington Elected Chairman of Manufacturers' Division

THE untimely death of Gordon Buchanan, shortly following his election at the St. Louis Convention as Chairman of the Manufacturers' Division, created a vacancy in this office, which, according to the Constitution and By-Laws of the Division must be filled by the vice-chairmen electing one of their own number. Accordingly, Vice-Chairman C. S. Huntington, Link-Belt Co., Chicago, Illinois, was unanimously elected as Chairman to fill the late Mr. Buchanan's unexpired term.

Mr. Huntington has long been active in the affairs of the Manufacturers' Division and is well and favorably known among the active membership. By both long experience and temperament he is admirably suited to undertake his new duties and his many friends among active and associate members will heartily concur in the wisdom of his selection.

Construction Industry and Recovery Economics[1]

By W. A. KLINGER

President, Associated General Contractors of America

IN RECENT years economists and politicians, for purposes of comparison, have fixed upon the year 1926 as a normal one and as the statistical base for the drive toward economic recovery. In that normal year construction presented a far different picture than it does in these times.

Construction volume for the year 1926 was \$9,500,000,000.

Construction volume for the year 1935 was \$3,200,000,000.

As we look back upon it now, the industry was then completely immersed in work. Construction was as abundant as the times merited. In volume, it was second only to agriculture, and it and its allied industries offered employment to one out of every six male employables in the Nation. Even then the industry had problems which it took very seriously. The problems were, however, of an entirely different character. They were problems within the industry. If I call them to mind you will remember how seriously we discussed them.

1. The creation of a credit structure for the industry.
2. A recognition of the general and sub-contractor as a processor entitled to a better purchase price than the consumer.
3. Uniform lien laws.
4. Open or closed-shop labor.
5. The foreign contractor.
6. The irresponsible contractor.
7. The evils of bid peddling.

In those days, we had serious discussions, interesting meetings, and crowded conventions. In 1926, the A. G. C., after five years of earnest work, produced a Code of Ethical Practice for the industry. I venture to say that in the past three years there haven't been ten contractors in the United States that have taken the time to read that Code, so troubled have they been with other problems.

[1] Reprinted from April, 1936, issue of "*The Constructor*".

◆ The construction industry and related groups may well view with real concern present policies of the Federal Government as they pertain to the expenditure of relief funds in the construction field. Mr. Klinger, in the following article, gives a comprehensive analysis of the existing situation, pointing out the disastrous consequences which would seem to result from a continuance of such policies and suggesting a program to effect a real recovery in the construction industry. Comments of crushed stone producers on this vitally important subject would be welcomed by the Editor.

In those days, the industry was a good place in which to make a living; a place where courage, determination and diligence were bound to produce success, because a man working in the industry had within himself the making of his own career. His relations to the industry were determined within himself. His market was a wide one, his customer was of his own choosing, his worries were confined to his own working forces, and to his competitors. Although the final rewards were not what they should have been, that was a problem recognized as inherent in the industry. There was always that satisfaction that comes with a job well done in a he-man's business. There is no other business or vocation that in its very nature produces so much self-satisfaction as that which emanates from a construction job completed on schedule. Even to this day, I never approach one of my jobs without an anticipatory thrill; without the satisfaction of seeing something tangible and useful emerge from the labor my organization has performed in the gathering of materials from every corner of the country, and the marshalling and co-ordinating of a working force to produce something that has never been done before at a price that is predetermined, and in spite of all the obstacles which God and sometimes man can put in the path.

Such was the construction industry in the period which ended with 1929. In a period of four years from 1926 to 1929, there was an average of \$9,250,000,000 per year expended on construction, with 1928 as the peak year—producing \$10,500,000,000. In the past four years, we have had an annual volume of less than \$3,000,000,000, an average of less than one-third of the former normal volume. In spite of

the seemingly tremendous efforts of the administration, construction volume from 1932, when it was $2,800,000,000, has seen but little change, and the consensus of available figures for 1935 places the volume at $3,200,000,000. There is, however, this striking difference. In 1926, which is generally considered the key year, the Public Works of the Nation amounted to 20 per cent of the construction program. By Public Works, I mean all construction performed with tax money by the combined Governmental agencies, from the Federal Government through to the smallest local unit. For 1926, the Public Works construction totalled roughly $1,880,000,000. The private construction work totalled $7,500,000,000, divided roughly as one-half residential, and one-half commercial and industrial. In 1934, the figures were reversed. The construction total was only $3,000,000,000, of which 80 per cent was either partially or wholly financed by the United States Government, and 20 per cent was private construction. The public construction program of 1935 was somewhat less than that of 1934, largely because of the big engineering construction undertaken in 1934. Taking the nation as a whole, privately financed work in 1935 increased over that in 1934, there having been about a 50 per cent increase in commercial and industrial construction, and about an 80 per cent increase in residential units. However, since commercial construction was 20 per cent of normal, a 50 per cent increase brought that to only 30 per cent of normal. Similarly, residential construction had dwindled down to 10 per cent of normal, so that an 80 per cent increase brought it to 18 per cent of its usual volume.

These figures show that as we open the year 1936, we find that the United States Government, through wholly or partially financed work, has become the purchaser of 75 per cent of all of the construction being sold in the Nation. It is the effect of that almost complete reversal in the cycle which I want to discuss with you tonight.

Public Works Theory

Beginning some three or four years before the crash, the A. G. C. first advanced the theory that construction was the balance wheel of industry, and that in times of business depression, governmental agencies should balance industry by increasing Public Works construction. The principle was sound. When an effort toward reconstruction of the Nation's business structure was undertaken in 1933, this idea was seized upon, not as a principle based on sound economics, but as a theory, and as a theory it has been experimented with ever since. It has been given the euphonious title "Priming the Pump," the theory having been that once the pump is primed, business will carry on. The basic principle of priming the pump is to put the water into the pump. This can't be done by taking a bucket of water and spilling it over the pump, letting the great bulk of the water waste itself in holes in the ground, as was done with the great Public Works appropriation of 1933. Neither can it be done by taking a bigger bucket of water and repeating the process of wastage on a bigger pump as was done by the appropriation of 1935. A pump cannot be primed by men that know nothing about the pump that is to be primed. It cannot be primed by a Social Welfare worker, a Professor of Economics, or a politically minded Lawyer. It must be done by somebody who knows something about the industry to be used as the primer. In other words, the effort should have been made by construction men. Somewhere in the administration set up, in a position of responsibility, there should have been somebody who knew something about spending money on construction, and getting value in return. To use the construction industry as the balance wheel, should in common sense have caused the enlistment of construction men rather than Social Welfare workers or Professors of Economics. That would have meant that construction work in this effort toward recovery would have been directed along well tried proven channels by men who knew what they were about, and whose entire training had been to convert the dollar into a maximum of useful construction, through the regular channels of industry. That would have meant that the construction industry could not be used for the experimental ground of the New Deal. Because the Government is making its recovery expenditures almost entirely construction, and because of the adaptability of our industry, all of the tampering with the fundamentals of economics, and all of the attempts to socialize industry, are being tried out in our field.

In the year 1933, we witnessed the first effort of the administration to prime the pump. For that purpose, Congress was asked to appropriate the unheard sum of $3,300,000,000, and, fully sold on the theory that this would prime the pump, Congress appropriated the money. The country looked forward to this expenditure of money as a great effort toward recovery, and the Nation as a whole, includ-

ing the construction industry, was eager for the experiment. Our market for private work was practically non-existent. This construction program financed with Federal money was the hope of the industry, and the one thing that held the industry together.

You will remember the turmoil of the times—the repeated promises made and withdrawn as to putting this program into effect, the appointment of Mr. Harold Ickes as Public Works Administrator; and the tremendous wage scale of $1.20 per hour he forced on construction throughout the Nation. That one order, emanating from so high a source, endorsing high wages in the big cities, and in many instances doubling prevailing wages in the smaller cities, swept all private construction out of the picture for the year 1933 and 1934. By so doing, it wrought a devastating blow to both labor and business. Investment in bricks and mortar, steel and concrete, could bring no return on that wage scale. There followed the almost entire cessation of private work and finally the Ickes program of PWA, so slow in coming into effect, and so encumbered with red tape, that instead of producing a mouthful for the construction industry, it produced only a bitter taste. Because of the exceeding slowness, caution, and the ignorance as to construction methods and procedure, the program broke down as far as any substantial lift to economic recovery was concerned. It broke down so far that the administration listened to the siren song of the Social Welfare worker, and took $834,000,000 out of what should have been Public Works Construction and devoted it to raking leaves under the famous CWA.

Priming the Pump

Following that program, the construction industry continued its struggle for existence through a period when private construction had shrunk to 15 per cent of its normal value. In the meantime, economists agreed that what was needed for economic recovery in the Nation was a revival of the durable goods industries, and this phase caught the public attention. In as much as construction is admittedly 75 per cent of the durable goods industry, it was merely another way of saying that construction had to be revived before the Nation could once more resume an even keel economically. Then followed the joint resolution of 1935, appropriating $4,880,000,000 as a bigger bucket full with which to prime the pump. Briefly, let us see what has become of this money. Before the President's signature was dry on the Act, Harry Hopkins had secured $580,000,000 for another leaf raking. In the accounting for the money as made by the U. S. Treasury on December 31, 1935 this $580,000,000 is not mentioned, the accounting being for $4,300,000,000. Of this sum certain commendable allocations were made to be expended through the existing Governmental Public Works Agencies, which were accustomed to expending money, and which were accustomed to getting full measure of return for such money, because these agencies expended that money through the regularly organized business channels set up for that purpose. That is true of the $500,000,000 turned over to the Bureau of Public Roads of the Department of Agriculture, all of which has been or will be spent by contract system. It was also true of the bulk of the $82,000,000 turned over to the Reclamation Service, and it was true of the 65 per cent of the $130,000,000 turned over to the Department of War to be expended with efficiency under the Engineering Corps. To Mr. Ickes and his Public Works Department was given $446,000,000. Let us here pause to say that Mr. Ickes has learned a lot about construction since his first Public Works appropriation; that he is thoroughly sold on the contract system of doing work, and that he has learned, and all his investigations have revealed, that the construction industry as a whole is to be trusted. Mr. Ickes may be counted on to spend this $446,000,000 largely by the contract system.

$514,000,000 has gone to CCC; the Resettlement Administration under Rexford Tugwell was allotted $181,000,000; WPA under Hopkins was allotted $1,162,000,000; Federal Emergency Relief Administration under Hopkins—$935,000,000; not allocated $55,000,000, an administrative cost of $200,000,000, and other comparatively small items account for $4,300,000,000.

It is interesting to know that up to the last Treasury figures available December 31st, 1935, the obligations from this sum were $2,340,000,000. The payments out of the sum were $1,672,000,000. The money allotted but not obligated was $1,900,000,000, and the money unexpended was $2,627,000,000.

A further study of these figures will show a total of $1,012,000,000 by contract, and $2,921,000,000 by day labor.

Some of the contract work has read into it compulsory inefficiency, couched under the term of "work hour allotments."

The ridiculous fallacy of compulsory wastage of work hours on certain projects need not be pointed out to construction minded men. To actually be compelled to thus waste labor is almost nauseating. It is inherently revolting to men whose whole training has been to make labor count in effective production. This is the compulsory inefficiency in some of the contract work.

Inefficient Day Labor

Of the $2,900,000,000 to be expended by day labor, all may be said to be highly inefficient, and not 20 per cent of this day labor will actually be converted into tangible wealth.

The Code Authority for General Contractors, and the Executive Committee of the A. G. C., anticipated what might happen, and after an appeal to the administration produced no results, went to Congress with a Resolution, which had the approval of both contractors' organizations, and the Construction League of the United States. Verbatim from the Resolution is Section 8 of the Joint Resolution of Congress appropriating the $4,880,000,000. This says: "Wherever practicable in the carrying out of the provisions of this Joint Resolution, full advantage shall be taken of the facilities of private enterprise." That section meant that that money was to be spent through the regular facilities of the construction industry by the contract system, and by the use of as much materials as are normally involved in a work hour of operations. If the intent of Section 8, which we thought was mandatory, had been carried out, construction as an industry would have survived the period of depression without excessive unemployment, without the breaking down of its organization, without 88 per cent of its existing units doing business at a loss or without profit as actually reported in Federal Income Tax returns. The depression wrought more business fatalities in construction than in any other industry. But in the expenditure of the money, Section 8 of the Act has been totally disregarded. I remember distinctly sitting at a Code Authority meeting in Washington when word came to us that the President himself wanted us to study and prepare a form of management contract, a form of fixed price contract, and an equitable equipment and personnel rental schedule that might be used by the Government in the prosecution of this construction work. Those studies were made, and the results passed on to the administration, but were never used. Mr. Harry Hopkins and Rexford Tugwell's ideas on how to spend the money in construction were preferred over those of the men who knew something about construction. Upon one occasion I publicly put this question to Harry Hopkins: "In the expenditure of this money can you not find a way to use the construction organizations of the country, not on a profit but on a subsistence basis?" His answer was a short terse "It could be done, but it won't." How little the construction industry is actually getting out of this program, and how much the ideas of Tugwell and Hopkins prevail, is shown by a recent news release which shows 2,500,000 men on day labor projects, and 10 per cent of that number on contract work.

Having analyzed the disposition of the funds, let us analyze the methods of disposition. Roughly $1,000,000,000 has been allotted to the contract system, of which less than $300,000,000 will be spent on building construction. With those allotments made through the regular channels through which the Government has previously been purchasing construction, we have no criticism to make. The great Reclamation Projects and Public Works Program have proceeded as expeditiously as could be anticipated. The Engineering Corps was set to go, and did go. But with the $446,000,000 allotted to PWA, if judged by results, the standard has been one of delay. As Ed Palmer says, "There have been instructions, restrictions, rules, regulations, revisions, orders, counter-orders, following each other in so hopeless a jungle that the entire PWA is floundering in a sea of paper." Eleven months after the passage of the Act, only $28,000,000 of the $446,000,000, or less than 6 per cent of the funds made available, have found their way into pay envelopes. A ridiculous burst of contract awards between November 20th and December 15th followed in an effort to make a showing by the 31st of December. But even now, only $126,000,000 out of the $446,000,000, or less than 30 per cent, has been contracted. Nevertheless, the construction industry as a whole welcomes this allotment. Even though the contractors and the subcontractors, and to some extent the processors and material dealers, will become experts in useless statistical work and red tape, the industry will, as a whole, absorb the additional expense, and give full value in that contract work.

Let us study the WPA system as differentiated from the PWA system. Out of the fertile brain of Harry Hopkins came that master mathematical calculation that $4,880,000,000 divided by 3,500,000 employables equalled $1,400.00, and that this $1,400.00

had to be the allotment per man year for labor and materials. Since men are to work 130 hours per month, or 1,560 hours per year, the answer is $.90 per hour for labor and material, and that $.90 has become the "God" of the WPA. To men who knew construction, these figures looked so ridiculous that it was hard to believe that men high in our Government could arrive at such a conclusion. In spite of the storm of protest that came from the industry, the ideas of the Social Welfare worker, and the Professor of Economics have been incorporated into the program. The answer has been compulsory inefficiency. In referring to the Supreme Court's decision adverse to NRA, the President said that the court was putting us back into the horse and buggy days. The administration has taken construction back to the horse and buggy days, and then taken away the horse.

Results of Program

The results of this program in operation have been as follows:

1. A complete breakdown in morale of the workers in the industry, which will only be revealed when we attempt to again function normally.
2. A year ago, the country accepted without question the assurance of the President that lower rates of pay would apply on relief work, that relief work would not be made attractive. That statement was given wide publicity. Not so wide has been the publicity concerning the retraction of that statement. After heavy pressure from an organized minority, the American Federation of Labor, the original wage scale structure was abandoned, and in our larger cities, the relief scale has been raised to $90.00 per month.
3. Relief wage scale has been made so attractive that relief workers are refusing to take jobs in private industry.

It is argued that by performing some labor in return for the relief payment, a worker will forget that he is on relief. I would not belittle that reasoning, but WPA has not so handled the problem. To argue that the men on WPA do not know their status is to insult the intelligence of the American workman. Even a casual observation of a relief job will convince you that the men know their status exactly. They not only know their status, they know they are statues. If the purpose of putting men to work is the worthy one of restoring morale, that can only be done by putting the men on contract work, without compulsory work restriction. Then their self respect will be returned to them by competition with their fellow men, and the result will be a building up of the morale or a severance from the payroll.

The most serious development of the past year, as far as the construction industry is concerned, is the establishment of a Bureau devoted to Public Works construction by day labor. If you think of WPA as an emergency bureau, take these words of Senator Clark of Missouri—"The fact is that we have never created a Government Department, Commission, or Bureau, which would not immediately start in to multiply itself by discovering new necessities for increased personnel and greater appropriations" and again, "The bulwarks of bureaucracy are a powerful and active lobby and an enormous engine of propaganda, supported by the taxpayers' money." Doesn't this fit in with some of the recent news releases from WPA?

Those who believe that the encroachment of day labor on construction is the general contractor's problem, should bear in mind that the general contractors are the shock troops in the battle, the subcontractor and the material men come next. A socialized industry with every worker looking to the Government for subsistence, means socialization from A to Izzard. There are no general contractors, no sub-contractors, no processors, no material dealers in Russia.

Industry's Problem

What to do about all of this is the general problem of our industry. As a first step, the industry must rid itself of the stigma of what is going on under the name of construction. The public believes that we are up to our necks in work, rolling in wealth, with our feet in the public trough. We must deny responsibility for, or association with, that part of the Public Works Program not being put through the regularly organized channels by the contract system, and we must deny this responsibility in no uncertain terms. If we do not do so now, the industry will bear the burden of that public stigma for years to come, and will suffer correspondingly.

As a second step, we must, if there is to be a further appropriation for Public Works by the new Congress as there undoubtedly will be, perform the patriotic duty of rationalizing that program in order to make it a successful one. Success in such a program means:

(A) The waste of not one single man-hour of employment on pick and shovel boondoggling, when there is so much useful work to be done.

(B) The greatest degree of employment in all capital goods industries dependent on construction, and not only in the pick and shovel industry.

(C) A maximum return in useful Public Works to the citizens of the Nation for their money.

(D) The establishment of a Department with a Cabinet Post devoted to Public Works by contract, rather than a Bureau devoted to public waste by day labor.

(E) Construction men spending construction money.

The way to achieve this program is to make a united demand on Congress. Surely Congress must be aware of what has been going on, and must be in a mood to listen to the reasoning of construction men about construction.

Optimistic Prospects

I do not wish to conclude this more or less pessimistic study of construction under the new deal without putting into it some optimism. All of us realize that there has been a tremendous back-lash in construction. It has been estimated that commercial and industrial construction is $26,000,000,000 in arrears in its logical expansion program. In addition to depreciation, obsolescence has been an increasing factor in creating that demand. President Roosevelt's Committee for Economic Recovery has advised that it would take ten years of 750,000 residential units per year to bring the nation to a point where its housing is properly taken care of. In Public Works, Mr. Chevalier calls attention to the fact that the emphasis should not be on safe driving on existing highways, but the reconstruction of highways and grade crossings to make driving safe. Mr. Greensfelder calls attention to the fact that American cities as a whole need an entire rebuilding to accommodate themselves to modern demands for proper merchandising, for proper traffic and for proper residential facilities. There is more to be done in construction work than has been done in all history. For four years the industry has been lying back, waiting for the Government to do something. It has been amply demonstrated that the Government is not capable of doing anything to restore construction to anything more than 30 per cent of normal.

Take home building as an example. For three years every prospective home builder has waited for the Government to hand him something on a silver platter with which to build himself a home.

After three years of effort the Government's greatly heralded Home Building Program has been an almost complete failure. Of all the Housing Rehabilitation and new residential construction in 1935, the Government financed only 8 per cent and it has probably expended much more on its five Housing setups in Washington than it has actually put into housing. Now, the administration realizes its error, and has within the last few weeks endorsed the proposed Wagner bill, which would do away with the setups known as FHA, HOLC, the Housing Division of PWA, and that in the Commerce Department, and all other setups, and substitute therefor the Wagner idea. Paraphrasing the familiar radio voice, "you and I both know" that it will be a year or two after the passage of the Wagner bill before any of its effect will be felt.

It is up to the industry itself to adopt and carry out a program that will produce construction. Such a program would have to consist of the following:

(1) We in the industry must unsell ourselves on the theory that the Government can help us.

(2) We must go ahead on the premise that we must create our own demand in construction, and use such work as is produced by the Government only to supplement private work. If we unitedly can convince the public of the fallacy of Government expenditure on so-called construction, and stop the terrific waste of money, thereby creating a move toward the balancing of the National budget, and the stability of the dollar, and dispelling the fear of inflation, we could bring vast stores of private money out of the cyclone cellar into the investment field.

Invest in Construction

We must cease waiting for the Government, discourage the public from looking to the Government, and sell construction on its merits. Cheap money is available as soon as it ceases being scared money. May I point out that there are inherently only two forms of investment for money—Government securities and capital goods securities. The Government is getting its money so cheaply because of a superabundance of money. That money will seek capital goods investment as soon as it shakes itself loose of its present fears. Its present fears are based on the Government expenditure program, and the rationalizing of that expenditure program is the patriotic duty of the construction industry.

Association Interest Stimulated by Series of Group Meetings

RETURNING from an extensive trip to the Southwest and intermediate points, Engineering Director A. T. Goldbeck and Administrative Director J. R. Boyd were highly gratified at the enthusiastic interest in Association activities displayed at each of a number of meetings of local producers held during the trip. Meetings were held in Columbia, S. C., on April 20, Kansas City, Mo., on April 27, St. Louis, Mo., on April 28, Nashville, Tenn., on April 29, Louisville, Ky., on April 30, Columbus, Ohio, on May 1 and Pittsburgh, Pa., on May 5. In addition to these meetings a three-day visit was made to Texas, where Mr. Goldbeck addressed the Twelfth Annual Highway Short Course held at College Station, Texas, the home of the Texas Agricultural and Mechanical College.

The primary purpose of the trip was to afford the executive officers of the Association an opportunity to discuss intimately with crushed stone producers the important work which the Association is conducting in their behalf, both engineering and administrative. In practically every instance the meetings were well attended. From the nature of the discussion which invariably followed the talks of Messrs. Goldbeck and Boyd, the vital interest which members of the industry have in the National Crushed Stone Association was clearly evident. It was most gratifying to learn first-hand of the strong conviction held by producers that under no circumstances should the valuable work of the Association, particularly in the field of research and promotion, be at all curtailed, and assurances of continued support were received on every hand.

An important feature of the trip was the opportunity afforded Mr. Goldbeck to contact the highway officials of a number of states, including North and South Carolina, Texas, Tennessee and Ohio. Problems of mutual interest were discussed at these conferences and members of the crushed stone industry may well take pride in the prestige which the work conducted in our research laboratory enjoys among highway officials.

The advantage of frequently contacting local producers has long been realized and the trip just concluded convincingly demonstrates the wisdom of such a policy. Additional trips to other important producing centers are contemplated and it is anticipated that before the end of the year practically all territories will have been contacted at least once.

Vice-President of British Institute of Quarrying Visits United States

FOR a number of years we have anticipated with pleasure the possibility that a representative of the British Institute of Quarrying, located at London, England, would be able to attend an annual convention of the National Crushed Stone Association, a friendly and cordial contact having been promoted between that organization and our own by W. E. Farrell, President of the Easton Car and Construction Co., who has been most courteously welcomed by the Institute upon his not infrequent trips to England. Though plans to have one of their representatives present at the St. Louis Convention last January did not materialize, we were especially gratified that Mr. Thomas Swan, Vice-President of the Institute of Quarrying at London, found it possible to make an extensive tour of the United States during recent weeks.

Shortly following his arrival in New York Mr. Swan travelled by air to New Orleans where he purchased an automobile and toured as far West as Salt Lake City. A brief visit was then made to the West Coast via plane, after which the return journey East was made by automobile. Mr. Swan then made a trip to Washington by plane where a visit was made to the offices and research laboratory of the National Crushed Stone Association. While in Washington, Mr. Swan made a brief inspection of some experimental bituminous construction projects being conducted by the highway department of the District of Columbia.

It was a distinct privilege to have the opportunity of meeting Mr. Swan and we thoroughly enjoyed his interesting observations, particularly with reference to the field of bituminous construction. Our best wishes go with him for a pleasant return trip to the British Isles and we hope he again may find opportunity to visit the United States in the not too distant future.

If you have no problems in your business, if you are perfectly satisfied with your product, your processes, and your costs in all respects, if you have no trouble from competition or other sources of worry, and are sure you are not going to have any for ten years to come, then you *may* not need research.—C. F. KETTERING.

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